A HYBRID VIRTUAL ENVIRONMENT INTERFACE TO ELECTRONIC WARFARE INFORMATION

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ABSTRACT
Since the end of World War II and the introduction of widespread use of radar, sonar, infrared sensors and other electronic surveillance systems, the task of information processing for military command and control operations has become excessively complex. A primary bottleneck in this scenario is in the use of traditional techniques for visualization and interaction with C^3I information. This type of information gathered from the three-dimensional world is visualized on two-dimensional displays requiring conscious interpretation by the operator to reconstruct an accurate image of the physical world.

We have developed an electronic warfare (EW) visualization workstation that displays EW information on a tactical 2D display concurrently with an immersive 3D display. The 3D display is intended to augment the tactical display when spatial information is paramount to performance of a task or comprehension of the current tactical situation. It is instantly available for use and can be easily removed from the operator's immediate work area. This hybrid interface allows EW data to be viewed in its most natural form, lessening the need for excessive interpretation of complex data. This paper describes the design and implementation of the EW workstation as well as future directions for development.

Keywords: virtual environments, immersive interfaces, electronic warfare, situational awareness, command and control

INTRODUCTION
Situational awareness in Naval command and control operations is inherently problematic due to the massive quantities of sensor data involved and the responsibility of many people, working together as a team, to both correctly interpret incoming data and quickly respond to it. Compounding the problem, traditional displays are extremely symbolic and non-intuitive creating a high cognitive demand on operators. Ambiguities can arise when multiple operators interpret the same data differently, often because the data is displayed in a different or incomplete form. Furthermore, sensor data from the three-dimensional world is presented in a two-dimensional form adding complexity to the task.

These pitfalls, combined with the importance of command and control operations to any military engagement, raise the issue of how best to improve the overall system in terms of error reduction, potential manpower reduction, and general increased effectiveness. This paper presents one such approach to this problem applying virtual environment technology to Naval operations where it will have the greatest impact towards improved human performance and reliability in these types of tasks.

We first look at how command and control operations are performed in current Naval engagements via a fictitious scenario narrative. This example illustrates a few of the unique problems associated with Naval command and control operations. We then describe a system, currently under development, that uses a hybrid immersive (3D) and flat (2D) display to visualize command and control information such that ambiguities are less likely to occur.

Current Electronic Warfare Command and Control Displays
For those readers who are unfamiliar with military polar displays or NTDS (Navy Tactical Data Symbols) symbology, we include schematic diagrams (see figure 1) and an NTDS legend (see figure 11 in the glossary). These will be referred to in detail in the scenario narrative in the next section.

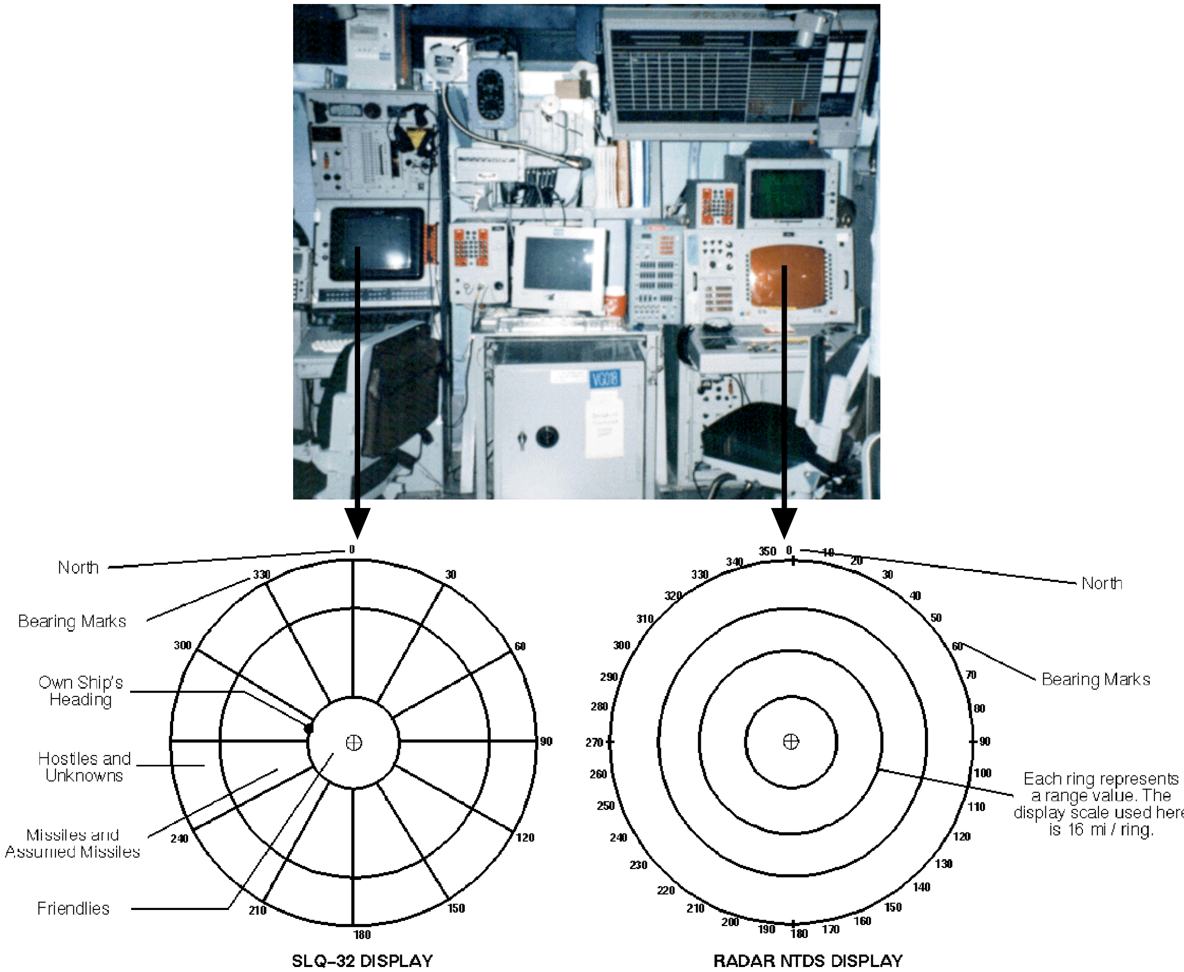

Figure 1: [top] The physical environment of the displays in CIC. [bottom] Schematic diagrams of the SLQ-32 and radar NTDS polar displays.

The top image in figure 1 shows the physical setting of a typical combat information center[1] (CIC). The SLQ-32(V)3 operator console is to the left and the radar NTDS polar display is to the right. The bottom image in figure 1 shows schematic diagrams of these displays. Note that the rings on the radar NTDS display represent range whereas rings on the SLQ-32 display represent symbolic regions. Friendlies reside in the inner ring, missiles in the center ring, and hostiles in the outer ring. The operators seated at these two consoles work together as a team to contact and identify all threats. Their objective is threefold:

- **Target association:** The SLQ-32 operator and the radar operator must be able to associate their contacts with one another in order to provide the maximum information about the target.
- **Target identification:** Once a contact is made, it must be labeled as hostile, friendly, or neutral and identified as to its type (F-14 aircraft, Harpoon missile, etc.).
- **Damage assessment:** The Captain must be certain a threat has been eliminated before dropping his defenses against it.

Furthermore, each of these objectives is greatly complicated by a densely populated theater of operation, more typical of the post-cold war era.

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[1] A glossary of terms is included as an appendix.

A Present Day Naval Engagement

An AEGIS class cruiser, the CG-47 Ticonderoga, is patrolling in the Persian Gulf to maintain shipping lanes for merchant ships. Commercial oil tankers have recently been harassed by OSA II fast attack gunboats. The Ticonderoga has been ordered to intercept the patrol boats and take whatever action necessary to end these attacks on unarmed commercial ships in international waters.

The Ticonderoga makes initial contact with a pair of unidentified surface craft approaching from shore at high speed. First, the SLQ-32 ESM (Electronic Support Measures) equipment (passive surveillance) intercepts the surface search radar on the craft as Racal Decca I-band at bearings 310 and 330. Within seconds the Ticonderoga SPY-1 radar operator has announced two contacts approaching at high speed on the same bearings. The SLQ-32 operator declares that the contacts are now radiating with targeting radars and requests permission to launch chaff. The Weapons Control Officer (WCO) requests permission to ready launchers and prepare to engage with Harpoon missiles. The Close-in Weapon System (CIWS) is placed in its standby mode.

One of the OSA II boats launches a missile. The Captain orders the WCO to engage the gunboats with Harpoon missiles. Simultaneously, a Standard Missile is launched to intercept the incoming OSA II missile (Figure 2 shows the SLQ-32 and radar displays for this point in this scenario.). The SLQ-32 displays two hostile surface craft at bearing 310 and 330 and a hostile missile. The SLQ-32 display does not show friendly missiles or range information. The radar displays two hostile surface craft, one hostile missile inbound, and three friendly missiles outbound. The range ring scale used here is 16 miles/ring.

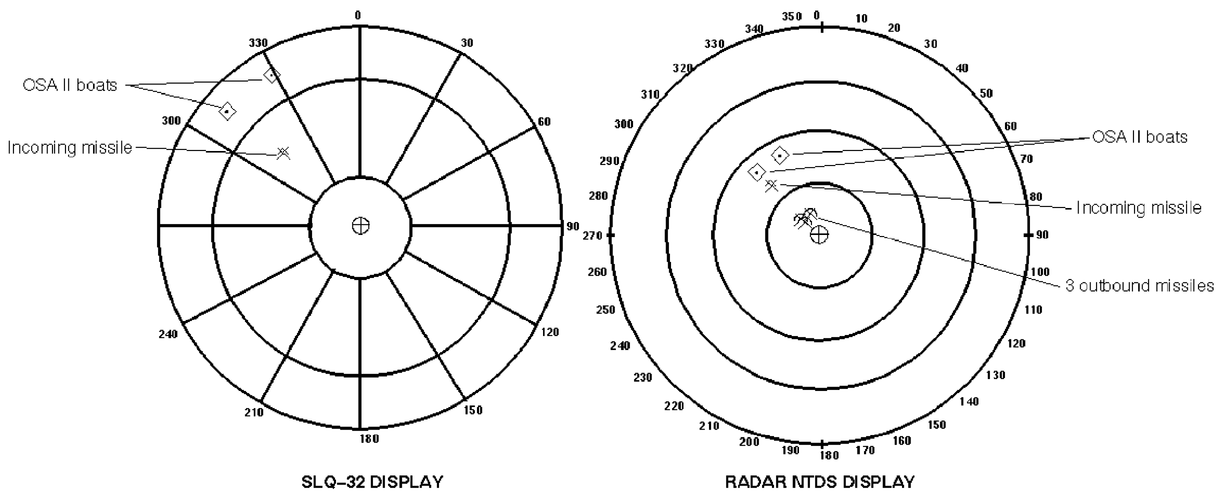

Figure 2: The SLQ-32 and radar displays immediately after the cruiser missile firings.

The SPY-1 operator announces he has an airborne contact approaching at a high rate of speed on bearing 030. The SLQ-32 ESM operator has a contact at that bearing but the system cannot resolve the ambiguities to provide a positive identification. Based on the current information, the operator identifies the threat as an F-14. But is it friendly or hostile?

The first Standard Missile launched misses its intercept of the incoming missile on bearing 310 and a salvo of two is ordered against the incoming threat. The incoming aircraft is identified as an F-14, but the Captain knows that there are no U.S. aircraft in the area. He concludes it is an F-14 that has been sold to a foreign nation and instructs the Identification Friend or Foe (IFF) operator to contact the aircraft and warn that its intentions have been interpreted to be hostile and if it does not alter its course it will be engaged. The plane does not respond and is now within launch range for its weapons; consequently, a salvo of two Standard Missiles are launched against it (Figure 3 shows the SLQ-32 and radar displays for this situation in this scenario.). The SLQ-32 displays two hostile surface craft at bearing 310 and 330, a hostile missile inbound, and a hostile aircraft at bearing 030. The radar displays two hostile surface craft, one hostile missile inbound, and seven friendly missiles outbound. Note the two outbound SM-2 missiles launched to intercept the incoming missile and the two outbound SM-2 missiles launched against the aircraft. The radar display quickly becomes cluttered around the center as a greater number of events take place nearer to the ship.

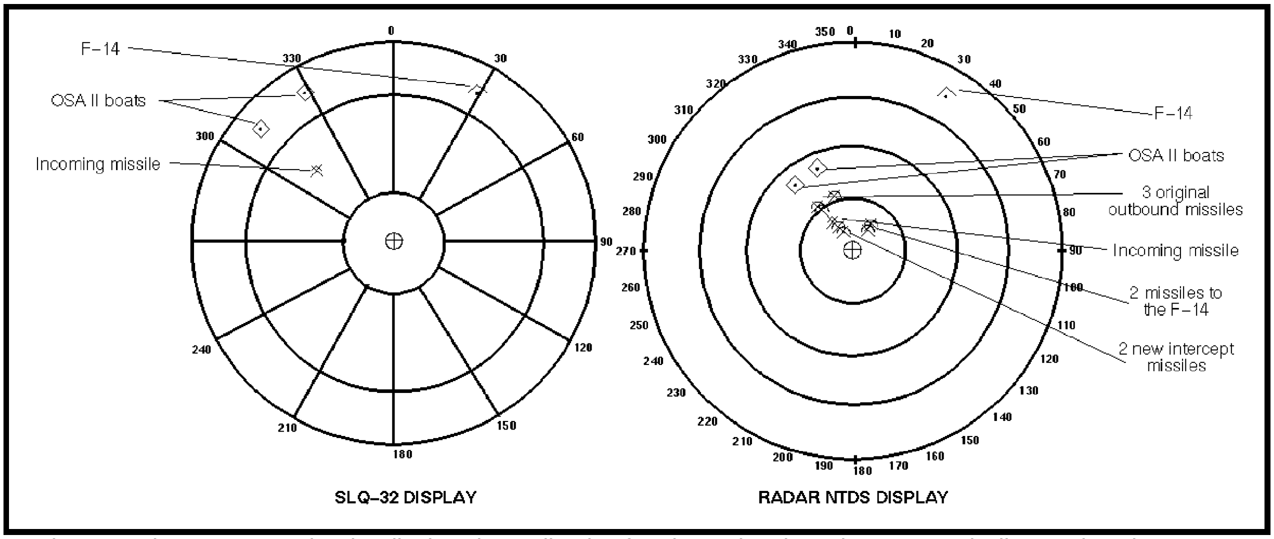

Figure 3: The SLQ-32 and radar displays immediately after the cruiser launches SM-2 missiles against the F-14.

The Naval Command and Control Domain

This fictitious scenario illustrates a recurrent problem in command and control applications; that of situational awareness. Essential to the defense of the ship is the Captain's knowledge of all players' positions, their intentions, and his options at every moment. The probability of success on a mission is directly related to the Captain's situational awareness. Thus, the goal of shipboard operators and equipment is to increase situational awareness quickly and accurately.

In this example, the operators of the SLQ-32 and the NTDS tactical display each had partial information of the scenario. The SLQ-32 operator had bearing and identification information while the NTDS display operator had range and bearing information. An essential component of their task is to resolve contacts on each of the two displays into single targets. That is, the F-14 aircraft, when contacted by the SPY-1 radar, presented a symbol on each of the two displays. The operators determined that the symbols were actually the same target by the fact that they were on the same bearing. However, even after this resolution, the NTDS operator was unable to positively identify the target. Altitude information is available to the NTDS operator only and must be explicitly requested by selecting the symbol on the display. The attitude of the aircraft (ascent or descent) must be determined by following the target over some time span (15 seconds is typical) to allow the radar to intercept the aircraft multiple times and to display the altitude numerically on the NTDS display. The primary problems in this system seem to be: (1) the displays are too symbolic and non-intuitive, and (2) there are too many operators working to form a single mental image. This requires that data fusion be done manually (and mentally) by the operators when it should be done, at least partially, by the system itself.

The Air Force has been actively pursuing these same goals in the area of cockpit design for a number of years (Stinnett, 1989). Their "virtual cockpit" is an interactive control and display system which presents all information relevant and necessary for the effective operation of the aircraft in three-dimensional virtual space in an effort to maximize the pilot's overall awareness and to provide control of his weapon systems. The basic premise on which their research has been founded is that present interfaces are limited by their use of unnatural operator input modes. To remedy this, they propose the use of natural human psychomotor controls to perform tasks; the end effect being the alleviation of operator sensory overload common in current interfaces.

These same principles apply to shipboard command and control operators in CIC. The domains differ because in order to effectively fight the ship, the CIC crew must operate as a team; each member responsible for a part of the overall task. Also, due to their greater payload and slower speed and maneuverability, ships tend to be the target of a greater number of threats making their operational theater much more highly populated.

The Force Threat Evaluation and Weapon Assignment (FTEWA) system has addressed these same issues, but from the perspective of antiair warfare (AAW) (Dennehy, Nesbitt & Sumey, 1994). FTEWA presents a panoramic, 3D view of the defended air space to the commander. It uses a wide HDTV display (1900x1024 pixels) controlled by a six degree-of-freedom Spaceball. All aspects of AAW are supported. Early indications are that the system eliminates much of the interpretive overhead and distracting information from view thus simplifying, to some degree, the task of situational awareness.

This leads us to believe that a significant part of the problem lies in the ways in which data is visualized and evaluated. The displays in question use symbology and text to convey spatial information (see figures 2 and 3). The primary variables of a contact of interest to the operator are its speed, direction (bearing: inbound or outbound), friend or foe identification (IFF), and track history. In order to accurately identify and associate contacts between the SLQ-32 and radar displays, a common factor is used (usually bearing line). However, in a densely populated region, this becomes difficult. Multiple contacts may be on the same bearing line or they may be near the horizon where the resolution of the radar limits its ability to disambiguate contacts. The same is true in damage assessment where it is necessary to note the loss of a contact to verify its elimination.

While FTEWA has chosen to use a single, unified 3D display, we believe that since a predominant part of the task *is* suitable to a 2D tactical view (as is currently used for the entire task), a 3D immersive augmentation to the tactical display would effectively facilitate the use of both 2D and 3D data visualization. Our approach is to represent ESM and radar information spatially using virtual environment technology and synchronized with a tactical view. A look into the potential future of general command and control operations will show that this information *can* be represented efficiently and effectively by providing the operator with a panoramic view of the world organized both spatially and temporally (Pruyn & Greenberg, 1993).

THE ELECTRONIC WARFARE VISUALIZATION WORKSTATION

The general objective of the Electronic Warfare (EW) visualization workstation is to improve EW operator performance. That statement can be interpreted in a number of ways. We define “improved performance” within this context to mean: less errors directly attributable to the human operator, faster task execution without sacrificing accuracy, and lower training requirements. To achieve these goals, the EW workstation must accomplish the following subgoals:

- Increased situational awareness for EW operator(s)
- Complete data representation
- Simplification of data correlation
- Common tactical display
- Data analysis tools including mission planning (“what-if” scenarios)
- Shortening of the decision-making chain
- Decrease cognitive demands on EW operator(s)

This section will describe the system in detail addressing these issues. We begin with a description of the EW simulation system on which the EW workstation is founded.

The Interactive Scenario Builder

The Interactive Scenario Builder allows users to create and visualize military combat scenarios. Developed by the Effectiveness of Navy Electronic Warfare Systems group (ENEWS), a part of the Tactical Electronic Warfare Division of the Naval Research Laboratory, the Builder specializes in EW simulation. Scenarios created and visualized with Builder have been used to support more than 30 Army, Navy, Marine, and Air Force EW programs. For nearly two decades, the ENEWS group has excelled in the creation of large-scale EW scenarios including: amphibious assault, counter-targeting, open ocean, littoral warfare, and special operations. Builder provides extensive capabilities in electromagnetic simulation and visualization, including a full range of emitter characteristics and scan patterns. Users can develop and visualize communications links, networks, spherical-earth platform motion, as well as accurate satellite modeling. The system provides extensive 2D and 3D viewing capabilities, allowing the user to quickly switch between the two. In the 2D mode, the Builder can show coverage areas that take into account the effects of propagation, terrain masking, jamming, and target characteristics. The 3D view allows real-time Digital Terrain Elevation Data (DTED) fly-overs with 3D emitter main beam and coverage volume visualizations. When used in conjunction with other ENEWS software programs, such as the PPI simulator and the Interactive Scenario Analysis Program (ISAP), additional visualization and analysis capabilities can be provided. Through the use of the Interactive Scenario Analysis Program, which provides on-line analysis of scenario pulse densities over time, users can quickly design, build and analyze scenarios within a common framework on a single platform. The current version of the Interactive Scenario Builder (as of 11/94) has the following capabilities:

- Incremental addition of platforms and their equipment through a graphical interface
- Link to a database compiled from a variety of intelligence sources
- Emitter scheduling and targeting
- Display platform’s characteristics, equipment and weapons
- Defining platform motion
- Instantaneous playback of the scenario at any time during the creation process
- Dynamic visualization of emitter’s main beam and coverage area with the effects of jamming and terrain masking
- Selectively display sites according to emitter function or C^2W characteristics
- Automatic ASMD missile and emitter scheduling through a production system
- 2- and 3-dimensional views of the scenario
- Display a variety of map data simultaneously
- Realistic sky, sea and terrain as backdrops for 3D views
- Special demonstration mode driven from a command-based script

Version 2.0 of Builder (anticipated completion date 9/96) will have the capabilities of the previous version plus:

- Undo-Redo capability
- Communications model
- Integrated EREPS (Engineer’s Refractive Effects Prediction System) and RPO (Radio Physical Optics) propagation models
- Underlying C++ scenario structure
- X/Motif-based interface (for portability)
- Utilization of the OpenGL standard graphics library (for portability)
- Organization of platforms in a display tree
- Point-and-click selection of a platform's equipment or weapons
- SAM/Air-to-Air logic
- Satellite tracking

The Hybrid Interface

The EW workstation consists of a large CRT screen rotated on its back and encased in a table to conserve space with a hand-operated immersive display within arm’s reach of the operator (see figure 4). The interface is currently operated by a traditional keyboard and trackball (or mouse) device. However, early indications are that users tend to feel more comfortable using their hands directly on the screen itself. We intend to investigate the implementation issues associated with a transformation to a touchscreen interface in the future. Until that time, the 2D display can be either flat, as shown in figure 4, or vertical, as shown in figure 6. The CRT screen can be any workstation-compatible video monitor of any size. We have chosen the largest size currently available (40” diagonal) so that we can investigate other configurations of the apparatus. For the purposes of shipboard deployment, a typical 20” diagonal monitor would be recommended to conserve floorspace.

The immersive display is a Fakespace, Inc. BOOM3C stereoscopic, full-color, high-resolution tracker/display. The BOOM uses two CRT displays behind wide-angle optics mounted on a high-fidelity, noiseless tracking arm. This device works exceptionally well for laboratory applications but will be unsuitable for shipboard deployment. The BOOM has a counterbalancing weight to lessen the weight of the hand-held display. However, the combined mass of the display and the counterbalance maintains a high moment of inertia and can be difficult to move quickly. Also, the movement of the counterbalance can be dangerous when used in confined spaces. Most importantly, the BOOM’s pedestal assumes that its orientation with respect to the floor (or more specifically, the gravitational vector) remains constant, which would not be the case on a ship. Fortunately, there is a derivative display based on the BOOM that maintains its desirable characteristics such as resolution and field-of-view while avoiding its undesirable characteristics such as the counterbalance and the level constraint. This display (called the PUSH display, also from Fakespace, Inc.) uses isometric sensing of body motion to determine movement direction and magnitude. It occupies very little space and could be easily configured for shipboard use.

For the most part, the operator will be working with the tactical display. This display shows map data, radar coverage areas, local platforms, and EW visualizations (the 2D view from Builder). For those moments when the operator requires an immersive view to disambiguate a target reference, to determine target altitude or attitude, or some other spatially dominant task, the immersive display can be swung into position. The operator can move at will through a virtual environment (the 3D view from Builder) analogous to that on the tactical display. The switch between views is virtually seamless with very little wasted effort (see figure 5).

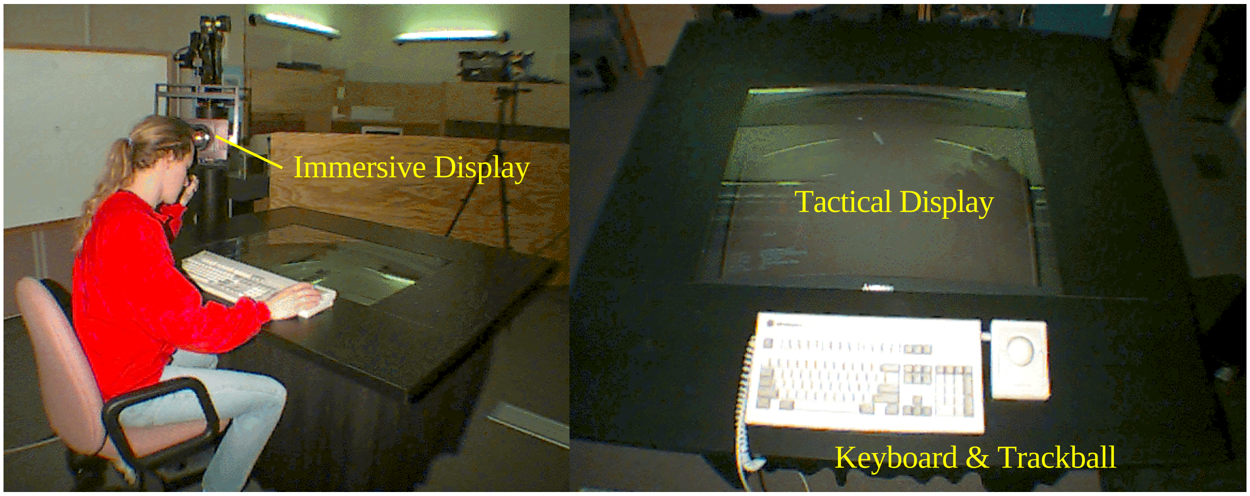

Figure 4: The current status of the implementation consists of a large 40” CRT monitor encased in a glass-topped table [right] and a Fakespace, Inc. BOOM3C display/tracker [left].

Figure 5: [left] The immersive display in use. [right] The tactical display in use.

Although the initial prototype shown in figures 4 and 5 uses a large monitor and BOOM display, for shipboard deployment, a smaller monitor and PUSH type display will be utilized. In this configuration, the operator is seated at the workstation and uses a keyboard and trackball (see figure 6). The tactical display is recessed into the desktop to preserve space. The immersive display is attached to an arm that rotates so that it can be swung into optimal viewing position very easily. We are continuing to redesign the immersive display mounting to the workstation in an effort to lessen the amount of vertical space occupied. The overall footprint of this configuration is relatively small. The workstation occupies 54”x58” of floorspace. Movement within the immersive environment is controlled via an isometric mechanism in the arm of the display. The operator leans forward into the display to move forward, leans back to move back, and can rotate about a point easily and naturally.

The power of this system lies in the way information is presented. We always choose to display information in its most natural form; 2D information on the tactical display, 3D information in the immersive display. However, since the two displays are really individual views of the same environment, there must be an intuitive and obvious connection between them to allow seamless alternation between them. We do this with a marker (hereafter referred to as the “you-are-here” marker) on the tactical display to show where the immersive display (the “virtual” viewpoint) currently resides. The position and orientation of the viewpoint are reflected in the movement and rotation of the marker on the tactical display (see figure 7). In this figure, the left view shows the tactical display with the you-are-here marker. The position and orientation of the marker indicates that the viewpoint is within view of the port side of a ship. The right view shows what would be seen in the immersive display associated with that tactical view. The you-are-here marker can be manipulated from the tactical display so that when the immersive display is used, it shows exactly what the operator needs to see, wasting neither time nor effort. The location of the virtual viewpoint can be moved to an absolute position, it can be tied to the movement of a platform, and the visualization parameters can be altered.

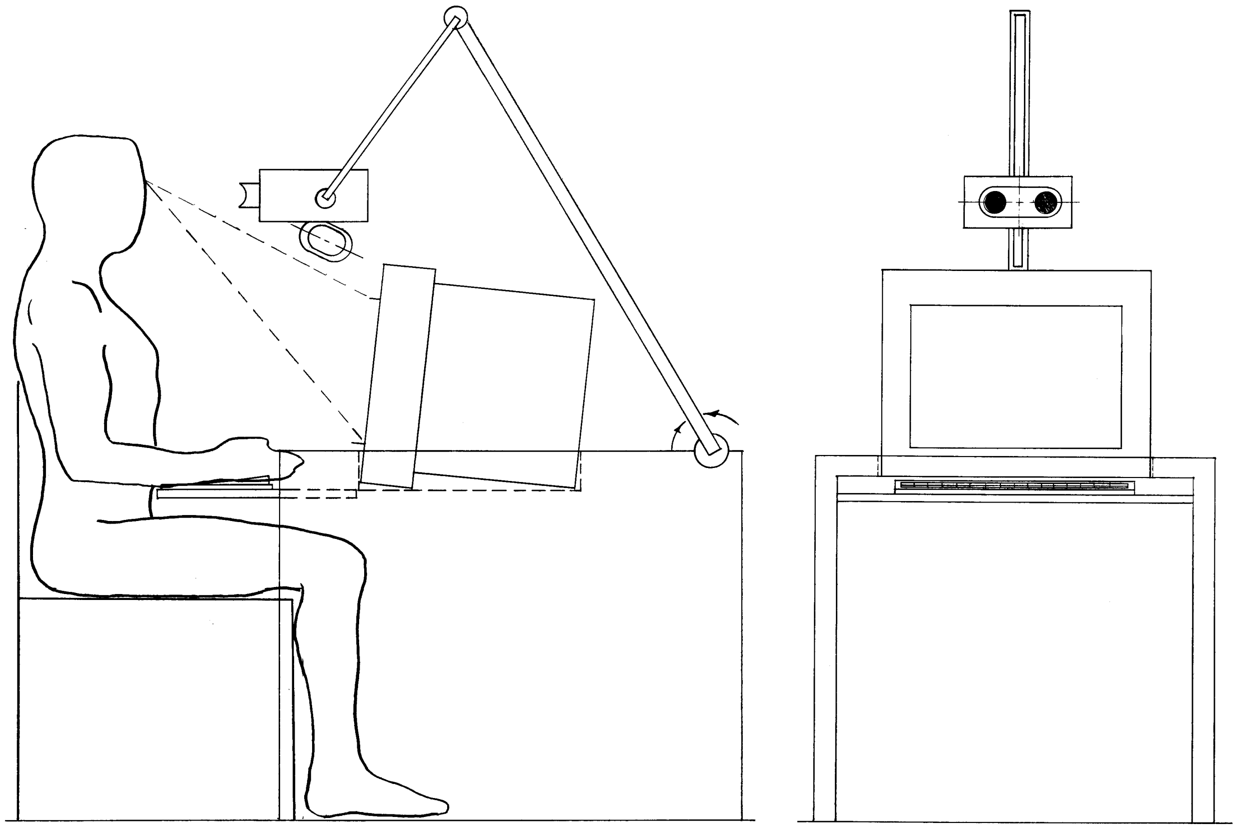

Figure 6: The shipboard configuration [left] side view, and [right] front view.

The operator's ability to understand spatial relationships is the primary reason for the use of an immersive display. Consequently, if the operator is easily confused or disoriented, the system will be ineffective and counterproductive. Although research continues in the area of navigation and orientation in virtual environments (Darken & Sibert, 1996a; Darken & Sibert, 1996b), we have adopted a technique of centering the tactical display on the you-are-here marker. Using this technique, the operator immediately knows not only where the viewpoint is (the you-are-here marker is always in the center of the display pointing forward) but also what is to the left, to the right, etc. We have found that this can help reduce the cognitive workload operators of these systems tend to encounter.

There are two communication channels between the displays. The two displays are actually separate applications that send and receive tactical information via DIS (Distributed Interactive Simulation) packets broadcast over the network (see figure 7). The you-are-here marker is simply another entity whose position and orientation information is sent to the tactical display. It has no effect on the data whatsoever but allows the tactical display to communicate with the immersive display via a general communications protocol. In this way, if further displays were to be added (e.g. another operator wishes to view the same data environment), the implementation would be trivial. It would simply connect to the network and receive and transmit DIS packets. Explicit communication between the tactical and immersive displays is accomplished via a special-purpose TCP/IP socket. This form of communication is reserved for non-tactical information such as visualization methods and parameters, viewpoint positioning, and time scale manipulations. If the operator wishes to view radar beams in the immersive environment, for example, they can be activated from the tactical display. This eliminates the need for detailed interaction techniques in the immersive environment that often tend to be cumbersome and awkward.

The tactical display is driven by a Silicon Graphics Indigo2 Extreme while the immersive display is driven by a Silicon Graphics Onyx Reality Engine 2. The immersive display requires high-end graphics capabilities to maintain a sufficient frame rate. While the tactical display does not have this same requirement, we have experienced problems with extreme lags due to the massive amounts of graphical data associated with large regions of DTED and map data, typical of this application.

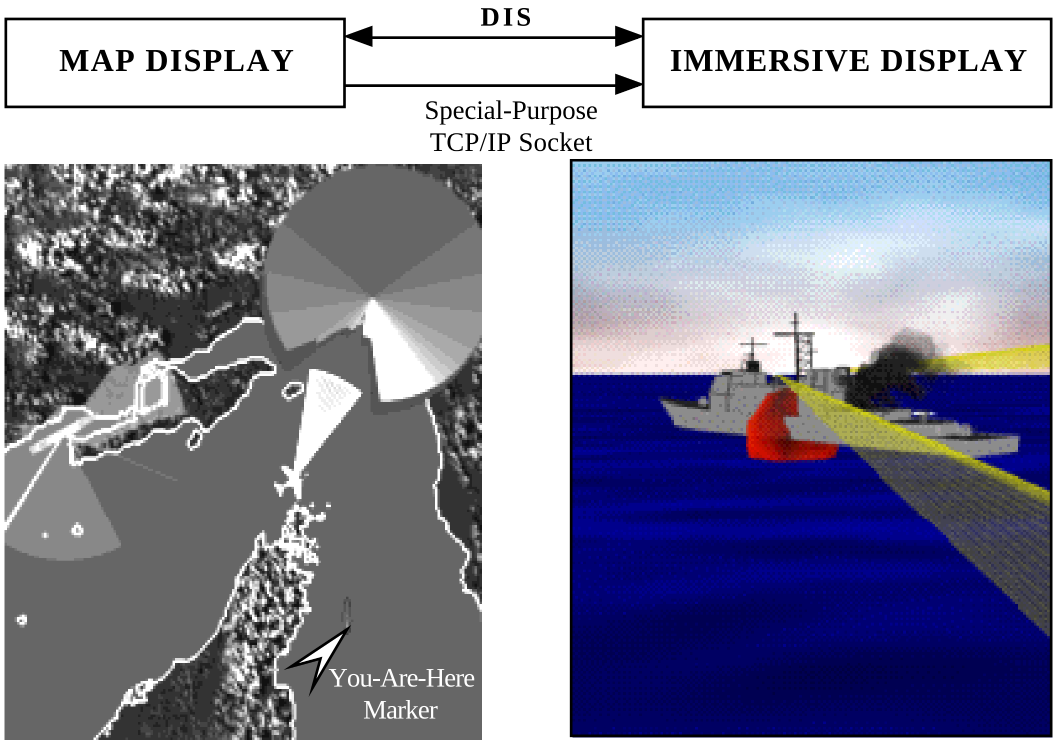

Figure 7: The system architecture showing a typical view on the tactical display and its corresponding view in the immersive display.

As an example of the use of this system, referring to the tactical situation described in the earlier narrative, the tactical and immersive views associated with figures 2 and 3 are shown in figures 8 and 9, respectively. The textual information has been added for identification purposes and would not actually be present on the displays. Also notice the you-are-here markers on the tactical views and the presence of the radar beams in the immersive views. These radar beams provide representative beam patterns and scan rates of the radars and can be turned on or off by the operator. In figure 8, the immersive view really doesn't add value to the information shown on the tactical display. All the relevant contacts are at the surface level. However, in figure 9, the immersive view clearly shows the altitude of the F-14 as it approaches the CG-47.

Mission Planning and Tactical Evaluation

Another configuration of the workstation facilitates multiple simultaneous users for the purposes of mission planning or tactical analysis. In this case, multiple users can gather around the table display (see figure 10). The tactical display is not centered on the you-are-here marker. Since users may face the table from any angle, it is advantageous to avoid imposing an explicit top and bottom to the screen if possible. At any time, one user can choose to view the simulation from the immersive viewer without disrupting the other participants. Also, the perspective view can be shown simultaneously on an external monitor so that the other participants can see what the immersive display user is seeing. This configuration requires no significant adaptations from the initial prototype configuration described in the previous section.

FUTURE WORK

Throughout this paper, we have alluded to several possible directions of development that the EW workstation may eventually follow. If the workstation is to be deployed for operational evaluation, the effects of ship motion on simulator sickness must be investigated. To our knowledge, the use of a shipboard immersive display has not yet been attempted. Simulator sickness is an extremely non-intuitive phenomenon. Its causes and side-effects are still relatively unknown for stationary displays. This study will be a major step toward the practical use of immersive displays in shipboard environments.

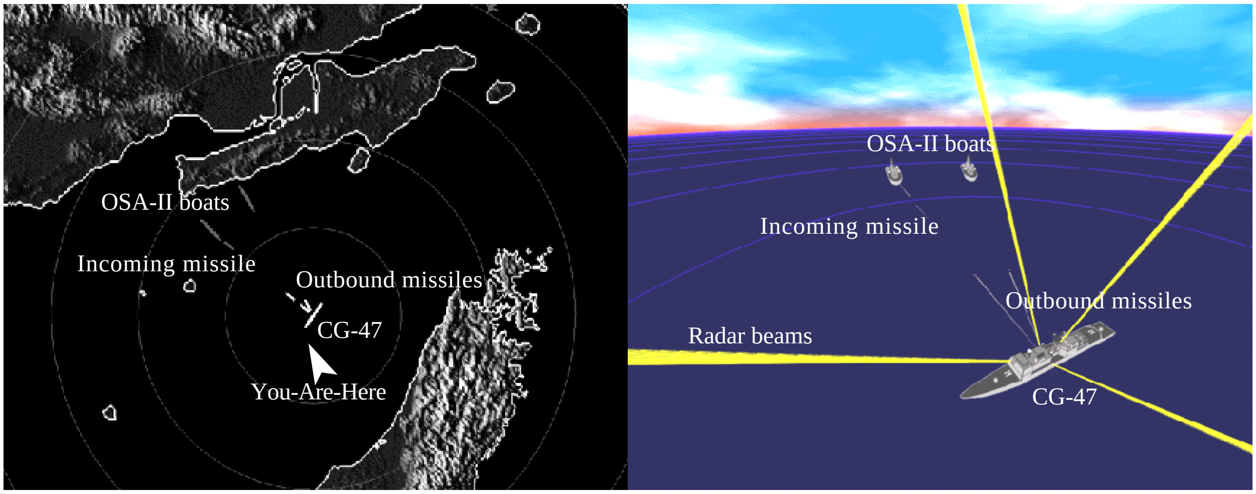

Figure 8: The tactical [left] and immersive [right] views corresponding with the SLQ-32 and NTDS tactical displays in figure 2.

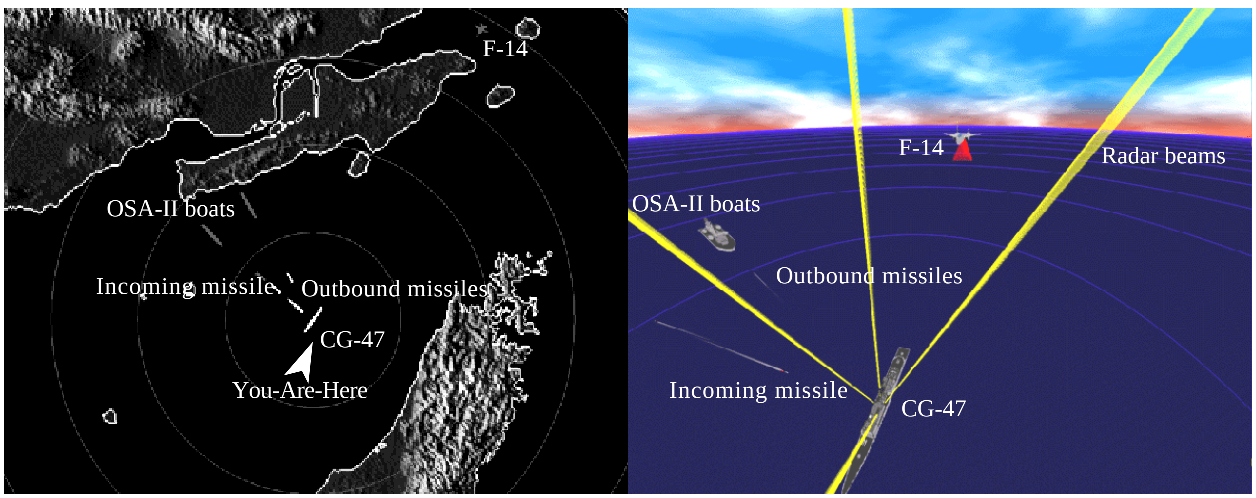

Figure 9: The tactical [left] and immersive [right] views corresponding with the SLQ-32 and NTDS tactical displays in figure 3.

The actual configuration of the workstation should eventually be smaller than it is currently. If the interface can be completely hand-driven, eliminating the need for the keyboard and trackball, the tactical display can be fully rotated down into the table. This configuration would not only have a smaller footprint but would require less vertical space. The question is in how to adapt the interface so as not to limit functionality. This is currently under investigation.

An alternative to the immersive display we describe here, which is mounted on a tracking arm, would be a see-through head-mounted display with adjustable transparency. This would eliminate the need for any movement whatsoever in switching between displays. When the immersive display is needed, the transparency would be adjusted off so the graphical environment can be viewed. When not needed, the transparency can be adjusted on so the tactical display screen can be viewed.

Lastly, a major problem with data fusion problems in general is the problem of representing uncertain data. We do not speculate on the nature or performance characteristics of EW equipment or how they will improve in the future. But we know that in any scenario, there is a level of uncertainty associated with information presented on these displays. This uncertainty must be represented in some way so that operators do not assume all data to be absolutely correct all of the time.

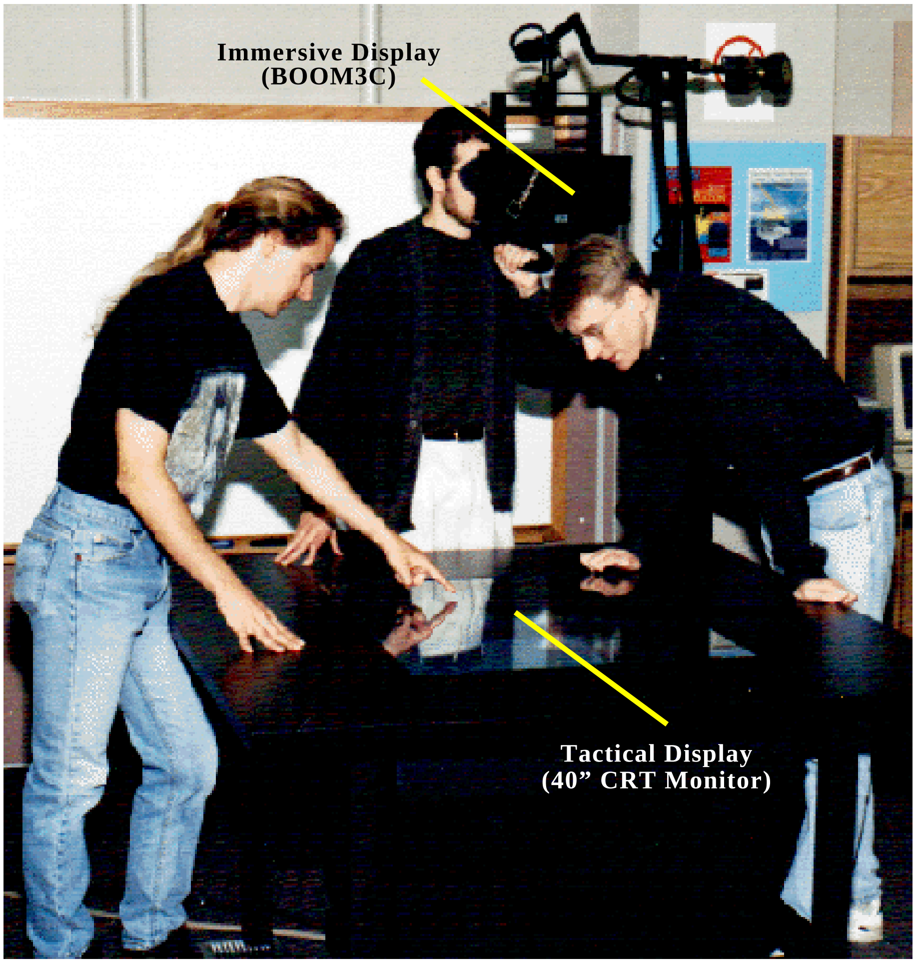

Figure 10: The EW Visualization Workstation shown with multiple simultaneous users.

CONCLUSIONS

Shipboard command and control is inherently problematic. We believe this is primarily due to the highly symbolic and nonintuitive display mechanisms currently in use. We have developed an electronic warfare (EW) visualization system that displays EW information on a tactical 2D display concurrently and synchronized with an immersive 3D display. The 3D display is intended to augment the tactical display when spatial information is paramount to performance of a task or comprehension of the current tactical situation. Therefore, it is instantly available for use and can be just as easily removed from the operator’s immediate work area. In many ways, this system can be thought of as an EW version of the Force Threat Evaluation and Weapon Assignment (FTEWA) system with an immersive augmentation. While FTEWA uses a single bird’s-eye 3D perspective view, our system uses two displays and communicates between them via DIS packets and a dedicated TCP/IP socket connection.

The EW workstation shows all relevant EW information in one place, at one time, and can be operated by a single person. However, before such a system can become operationally feasible, a complete task analysis must take place to ensure that all aspects of EW operations are accounted for. The tactical display we show here is not specific to this application. Our intention was to use a common tactical display that could be used for other shipboard operators as well as EW operators. The functionality of the Interactive Scenario Builder offers in-depth mission planning and “what-if” scenario analysis. Finally, if the EW workstation is, in fact, a more intuitive and natural interface to EW information, we expect to see a training payoff as operators will adapt to the system with greater ease than conventional displays that require symbol memorization and interpretation.

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GLOSSARY

C^3I: Command, Control, Communications, and Intelligence

AEGIS: AEGIS is the shipboard weapons system (Weapons System Mark 7) which is characterized by its integration of the AN/SPY-1 phased array radar, Command and Decision system, Weapons Control system, Fire Control system, Guided Missile Launching system, Standard Missiles (SM-2), and Operational Readiness Test system.

OSA II: The OSA II boats are fast attack craft with four surface-to-surface missiles and 30mm guns. It is 127 feet long, has a beam of 25 feet and draws 9 feet of water. It has a range of 500 miles at a speed of 35 knots.

SLQ-32: The SLQ-32 is a shipboard ESM (Electronic Support Measures) and ECM (Electronic Countermeasures) system with a CRT polar format display which represents various classifications of intercepted emitters.

ESM: Electronic Support Measures involves the task of searching for, intercepting, identifying, and locating sources of radiated electromagnetic energy for tactical purposes.

SPY-1: The AN/SPY-1 radar is an electronically scanning, multi-function, three-dimensional, phased array radar that automatically detects and tracks targets at long-range.

Chaff: Chaff is typically strips of lightweight metal foil which can be dropped from an aircraft or expelled from shells or rockets by surface ships to produce radio frequency (RF) echoes in a region of space. It is an electronic countermeasure (ECM) used to mislead the radar operator or signal processing of a hostile radar.

Harpoon: The Harpoon is probably the most widely deployed Western antiship missile (ASM). It was originally developed for air-to-surface use and also exists in surface- and submarine- launched versions.

CIWS: The CIWS (also known as the Vulcan/Phalanx) is the ship's last line of defense against incoming missile or low-flying aircraft attacks. The system features a 3000 round/min firing rate and depends on its ability to apply an intense barrage in the path of the incoming missile or aircraft.

CIC: The Combat Information Center is that part of the ship where all the sensor and weapon information is combined to provide the commanding officer with the tactical picture necessary to fight his ship.

NTDS: Navy Tactical Data Symbols (see figure 11)

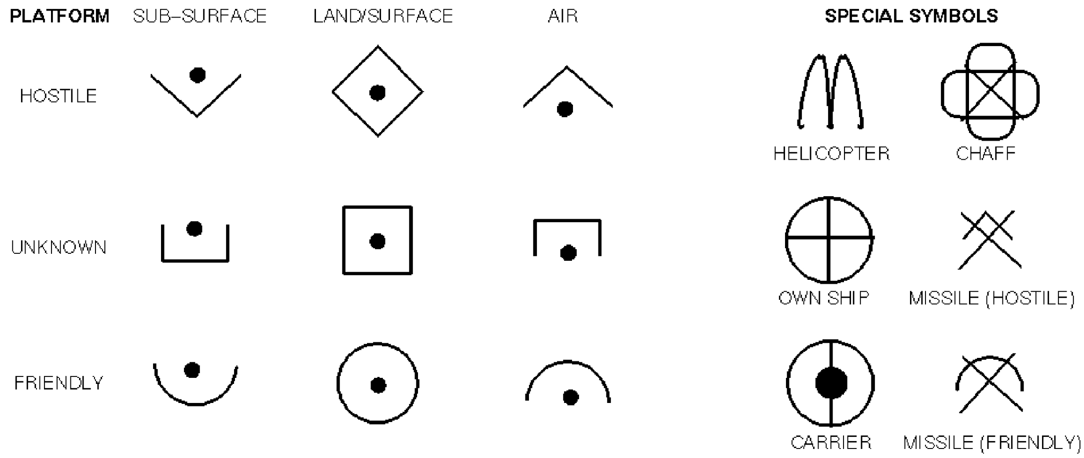

Figure 11: The Navy Tactical Data Symbols chart. These symbols are used on the schematic display diagrams in figures 2 and 3.

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